US009261093B2

(12) United States Patent
Skelton

(10) Patent No.: **US 9,261,093 B2**
(45) Date of Patent: **Feb. 16, 2016**

(54) **HEATER AND PUMP PERFORMANCE DIAGNOSTIC FOR A HYBRID BATTERY THERMAL SYSTEM**

(75) Inventor: **Scott M. Skelton**, Belleville, MI (US)

(73) Assignee: **GM Global Technology Operations LLC**, Detroit, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 689 days.

(21) Appl. No.: **13/585,889**

(22) Filed: **Aug. 15, 2012**

(65) **Prior Publication Data**

US 2014/0052411 A1 Feb. 20, 2014

(51) **Int. Cl.**

G06F 11/30	(2006.01)
F04B 51/00	(2006.01)
H01M 10/42	(2006.01)
B60L 1/00	(2006.01)
B60L 1/02	(2006.01)
B60L 11/14	(2006.01)
H01M 10/625	(2014.01)
H01M 10/6568	(2014.01)
B60H 1/00	(2006.01)
H01M 10/652	(2014.01)
H01M 6/50	(2006.01)
B60L 11/18	(2006.01)

(52) **U.S. Cl.**

CPC ***F04B 51/00*** (2013.01); ***B60L 1/003*** (2013.01); ***B60L 1/02*** (2013.01); ***B60L 11/14*** (2013.01); ***B60L 11/1861*** (2013.01); ***B60L 11/1874*** (2013.01); ***B60L 11/1875*** (2013.01); ***H01M 10/4207*** (2013.01); ***H01M 10/625*** (2015.04); ***H01M 10/652*** (2015.04); ***H01M 10/6568*** (2015.04); *B60H 1/00278* (2013.01); *B60H 1/00885* (2013.01); *B60L 11/187* (2013.01); *B60L 2240/36* (2013.01); *B60L 2240/421* (2013.01); *B60L 2240/545* (2013.01); *B60L 2240/662* (2013.01); *B60L 2250/10* (2013.01); *H01M 6/5038* (2013.01); *H01M 10/5038* (2013.01); *H01M 10/5077* (2013.01); *H01M 2220/20* (2013.01); *Y02T 10/642* (2013.01); *Y02T 10/70* (2013.01); *Y02T 10/7005* (2013.01); *Y02T 10/705* (2013.01); *Y02T 10/7044* (2013.01); *Y02T 10/7077* (2013.01); *Y02T 10/7291* (2013.01); *Y02T 90/16* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,007,315	A *	2/1977	Brinkmann et al.	429/62
5,665,484	A *	9/1997	Bolger	429/62
2002/0034682	A1 *	3/2002	Moores et al.	429/120
2003/0098009	A1 *	5/2003	Saito et al.	123/299
2009/0139781	A1 *	6/2009	Straubel	180/65.1
2009/0249807	A1 *	10/2009	Nemesh et al.	62/117

(Continued)

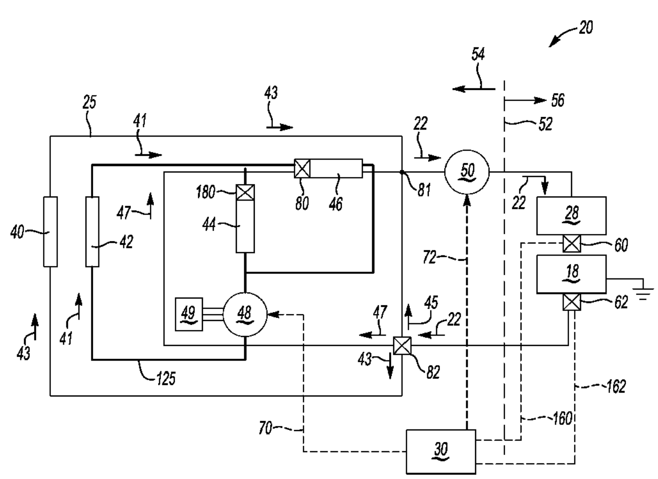
Primary Examiner — Paul D Lee

(74) *Attorney, Agent, or Firm* — Quinn Law Group, PLLC

(57) **ABSTRACT**

A system includes a controller, battery pack, fluid, heater, a pump that circulates the fluid to the battery pack through the heater, and a temperature sensor positioned between the heater and battery pack. The controller processes temperature signals from the sensor, diagnoses the pump and heater by turning on the pump in response to a received enabling signal, calculates an absolute value of a temperature gradient of the fluid while the pump remains on, and records a passing pump diagnostic code if the absolute value of the temperature gradient exceeds a calibrated rate. The controller executes a heater diagnostic, after calculating the absolute value of the temperature gradient, only when heating is requested or the absolute value of the temperature gradient does not exceed the calibrated rate. The heater diagnostic includes turning off the pump, cycling the heater on and off, and monitoring the temperature signals for a temperature rise.

14 Claims, 2 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0009246	A1*	1/2010	Maitre et al.	429/62
2011/0214930	A1*	9/2011	Betts et al.	180/65.1
2011/0229749	A1*	9/2011	Kim et al.	429/120
2012/0028087	A1*	2/2012	Gaben et al.	429/50
2012/0109547	A1*	5/2012	Willey et al.	702/58
2012/0301755	A1*	11/2012	Axelsson et al.	429/62
2013/0052490	A1*	2/2013	TenHouten et al.	429/50

* cited by examiner

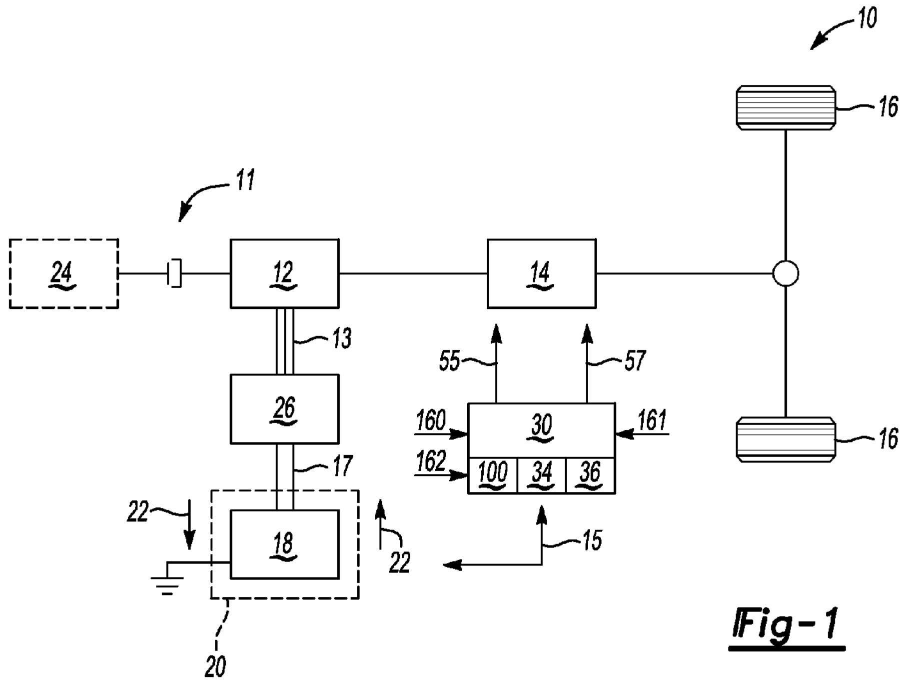

10
11
24
12
14
16
16
13
26
17
18
20
22
22
55
57
30
160
161
162
100
34
36
15

Fig-1

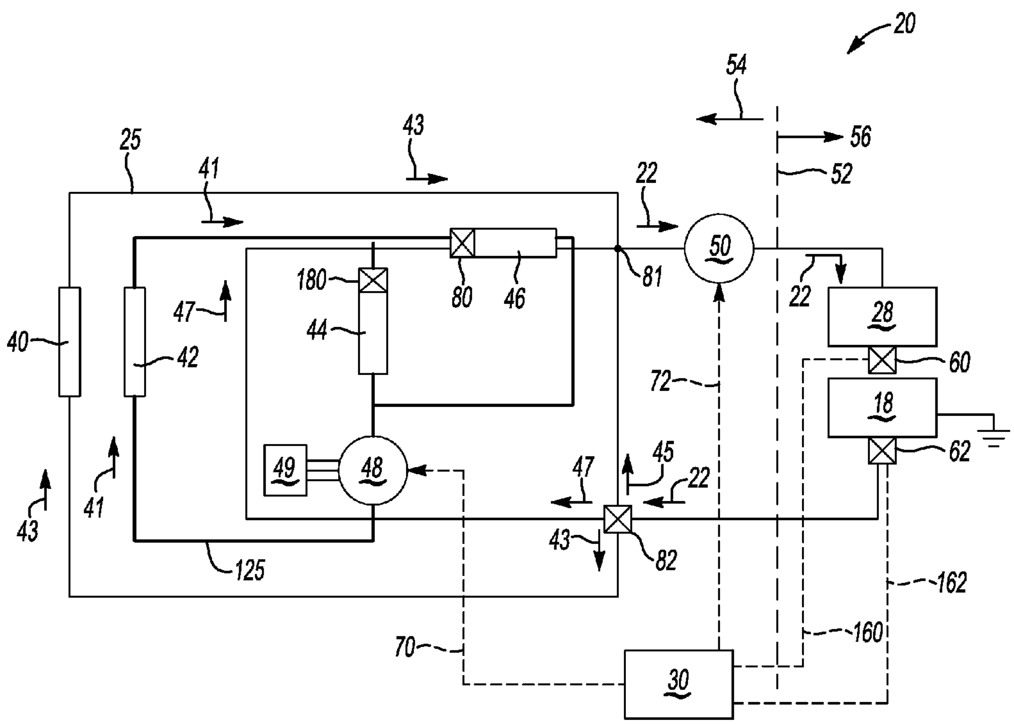

20
54
56
52
25
41
43
22
50
81
180
80
46
22
28
60
47
44
72
40
42
18
62
49
48
47
45
22
41
43
43
82
125
162
160
70
30

Fig-2

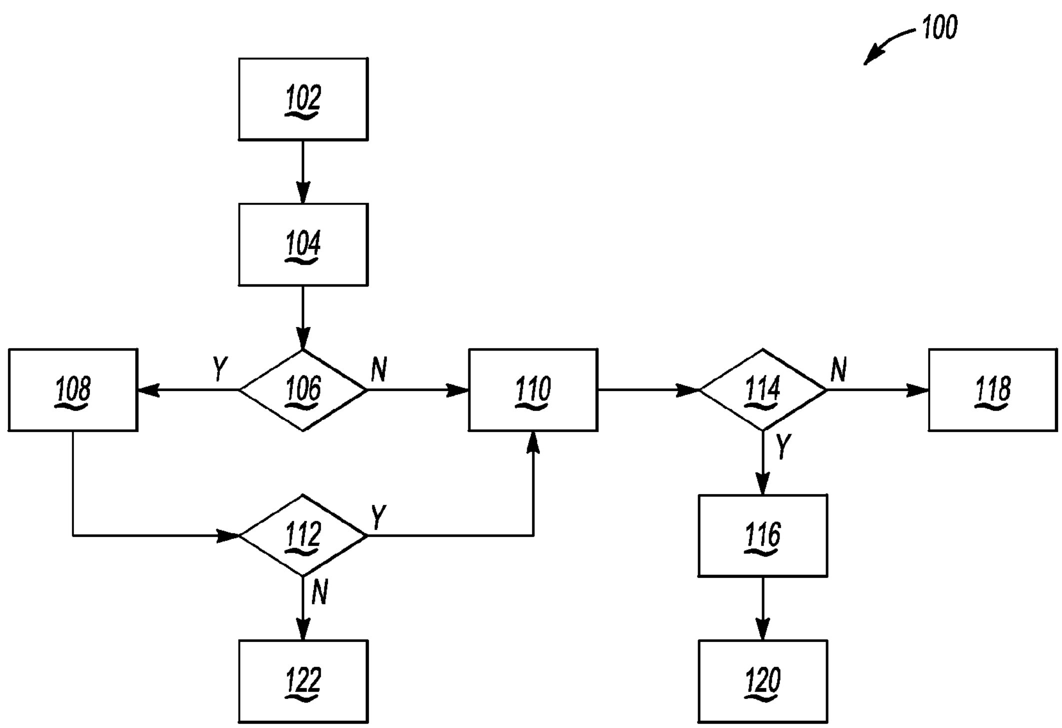


Fig-3

HEATER AND PUMP PERFORMANCE DIAGNOSTIC FOR A HYBRID BATTERY THERMAL SYSTEM

TECHNICAL FIELD

The present disclosure relates to a performance diagnostic for a pump and heater of a thermal system for heating or cooling a hybrid battery pack.

BACKGROUND

Certain vehicles are propelled at least part of the time using electrical energy drawn from a high-voltage DC battery pack. The battery pack energizes one or more polyphase electric traction motors via a power inverter. Hybrid electric vehicles selectively use an internal combustion engine as a source of input torque to a transmission, alone or in conjunction with the traction motor(s), while extended-range electric vehicles use a smaller engine only when needed, and solely to power an electric generator. Battery electric vehicles forego use of the small gas engine, and instead operate using stored electrical energy or regenerative braking energy. All three vehicle configurations can operate solely on electricity in what is referred to as an electric vehicle (EV) mode.

In all of the above vehicle embodiments, the high-voltage DC battery pack is used to alternatively store and deliver the substantial amounts of electrical energy needed for driving the traction motor(s). The battery pack, which may consist of multiple battery modules each containing multiple cylindrical or flat/tabular battery cells, generates heat in operation. Effectively dissipating the generated heat is essential to optimizing vehicle performance. As a result, thermal systems are used in conjunction with battery packs to circulate a volume of a suitable cooling fluid through the battery pack and any associated power electronics.

SUMMARY

A system is disclosed herein that includes a battery pack, heat transfer fluid, a heater, a pump that circulates the fluid to the battery pack through the heater, and a temperature sensor. The temperature sensor is positioned in a fluid loop, e.g., between the heater and the battery pack or elsewhere, and measures a temperature of the fluid.

The controller selectively turns on the pump in response to a received enabling signal, e.g., a key-on signal when the system is used as part of a vehicle, and thereafter calculates an absolute value of a temperature gradient of the fluid while the pump remains on. The controller records a passing pump diagnostic code if the absolute value of the temperature gradient exceeds a calibrated rate. The controller then executes a heater diagnostic only when heating is requested via control logic or the calculated absolute value of the temperature gradient does not exceed the calibrated rate. Execution of the heater diagnostic includes turning off the pump, cycling the heater on and off to generate a slug of heated fluid, and monitoring the temperature signals from the temperature sensor for a sufficient temperature rise.

A method is also disclosed for diagnosing the above system. The method includes measuring a temperature of the fluid, receiving an enabling signal via the controller, and turning on the pump in response to the received enabling signal. The method also includes calculating an absolute value of a temperature gradient of the coolant using the temperature signals while the pump remains on, and then recording a passing pump diagnostic code if the absolute value of the calculated temperature gradient exceeds a calibrated rate. That is, the actual temperature gradient can be a negative value. In such a case, the temperature gradient must be less than a calibrated rate. Use of an absolute value for the required comparison allows use of a single calibrated rate.

Additionally, the method includes executing a heater diagnostic, after calculating the absolute value of the temperature gradient, only when battery heating is requested or when the absolute value of the calculated temperature gradient does not exceed the calibrated rate, including turning off the pump, cycling the heater on and off, and monitoring the temperature signals for a calibrated temperature rise as noted above.

The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of a vehicle having a high-voltage battery pack, a thermal system used to heat or cool the battery pack, and a controller which diagnoses the performance of a pump and a heater of the thermal system.

FIG. **2** is a schematic illustration of an example thermal system that may be used aboard the vehicle shown in FIG. **1**.

FIG. **3** is a flow chart describing an example method for diagnosing the pump and heater of the thermal system shown in FIG. **2**.

DETAILED DESCRIPTION

Referring to the drawings, an example vehicle **10** is shown schematically in FIG. **1** having a high-voltage electric traction motor **12**, a transmission **14**, and a set of drive wheels **16**. The vehicle **10** also includes a rechargeable battery pack **18** that is cooled via a thermal system **20**, an example of which is described in greater detail below with reference to FIG. **2**. The thermal system **20** circulates a heat transfer fluid (arrow **22**), e.g., coolant or air, through the battery pack **18** in order to provide heat to or dissipate heat from the battery pack **18** during its operation. While not shown in FIG. **1** for added simplicity, the same thermal system **20** may be used to circulate the fluid (arrow **22**) through the various power electronics used to control the traction motor **12**, e.g., a traction power inverter module (TPIM) **26**, an auxiliary power module/DC-DC converter (not shown), etc.

A controller **30**, the function of which is described in detail below with reference to FIG. **3**, is in communication with the various components of the thermal system **20** over a communications bus **15**, for instance a controller area network (CAN) bus of the type known in the art. To meet on-board diagnostic requirements in an energy efficient manner, the controller **30** executes instructions embodying a method **100** to diagnose the performance of primary components of the thermal system **20**, including a heater **28** and a pump **50** as shown in FIG. **2**. The present diagnostic approach is intended to function as an energy-efficient alternative to conventional diagnostic methods by providing for diagnosis of the pump **50** of FIG. **2** without always requiring use of the heater **28** in the conventional manner. Thus, use of the present approach may provide certain energy savings while also reducing unnecessary usage of the heater **28**.

The vehicle **10** shown in FIG. **1** may include an optional internal combustion engine **24** as shown in phantom, for instance when the vehicle **10** is configured as a hybrid electric vehicle or an extended-range electric vehicle rather than a battery electric vehicle. In one possible embodiment, the engine **24** may be connected to the input of the traction motor **12** via an input damping clutch **11**. Torque from the engine **24** can be used to power the fraction motor **12** when needed, either directly or via generation of electricity. The engine **24** may be alternatively connected to the transmission **14** to deliver input torque directly to the transmission **14** in another configuration.

The thermal system **20** and accompanying method **100** described herein may be used with any high-voltage battery pack **18** that uses a thermal system such as the thermal system **20** for heating and cooling. While vehicle propulsion is a suitable application for the battery pack **18** and the traction motor **12**, the present approach may be used in non-vehicular applications using a battery similar to the battery pack **18** shown in FIG. **1** without departing from the intended inventive scope. Thus, the configuration shown in FIG. **1** is intended as an illustrative, non-limiting example embodiment.

The example traction motor **12** shown in FIG. **1** draws electrical energy from and delivers electrical energy to the battery pack **18**. The battery pack **18** thus forms a rechargeable energy storage system for energizing all high-voltage electrical components used aboard the vehicle **10**. As used herein, the term "high voltage" refers to a voltage level in excess of any auxiliary/12 VDC voltage levels normally used to power auxiliary vehicle systems such as audio systems, lighting, and the like. The battery pack **18** may be rated for approximately 60 VDC to over 300 VDC depending on the power rating of the fraction motor **12**. Other battery designs may be used at lower voltage ratings. However, the need for a dedicated fluid cooling loop decreases with decreasing voltage output, and thus the remaining examples will refer back to the high-voltage components shown in FIG. **1**.

When the fraction motor **12** is configured as a polyphase AC induction machine, the vehicle **10** may also include the TPIM **26** noted above. The TPIM **26** is electrically connected to the battery pack **18** via a high-voltage DC bus **17**, and to the traction motor **12** via a high-voltage AC bus **13**. The TPIM **26** may be controlled via pulse-width modulation and high-speed semiconductor switching, as is well understood in the art, in order to convert AC power generated by the fraction motor **12** into DC power suitable for storage in the battery pack **18**, and to convert the stored DC power back to AC power as needed for powering the traction motor **12**. Such functions generate substantial amounts of heat, and thus require fluidic cooling via the thermal system **20**. Likewise, when the battery pack **18** is used in cold weather, the performance of switching components and other electrical devices can degrade, and thus the thermal system **20** can be used to heat the battery pack **18** as needed.

The controller **30** shown in FIG. **1** executes instructions or code embodying the present method **100** from a tangible, non-transitory memory device **36** using received temperature signals (arrows **160**, **162**), the origins of which are explained below with reference to FIG. **2**. Execution of the method **100** allows a processor **34** of the controller **30** to diagnose the performance of the thermal system **20**. The controller **30** may be configured as a digital computer having, as the memory device **36**, read only memory (ROM), flash memory, and/or other magnetic or optical storage media.

The controller **30** also includes sufficient random access memory (RAM), electrically-erasable programmable read only memory (EEPROM), and the like. Additionally, the controller **30** may include a high-speed clock, analog-to-digital (A/D) and digital-to-analog (D/A) circuitry, and input/output circuitry and devices (I/O), as well as appropriate signal conditioning and buffer circuitry to provide a fully functional hardware and software control device.

Heating control signals (arrow **161**) may be generated or received by the controller **30** in an example embodiment to determine when battery heating is required of the thermal system **20**. That is, battery heating is a result of controls logic which looks at several parameters such as battery temperature, coolant temperature, ambient temperature, battery state of charge (SOC), vehicle operating mode such as charging, driving, etc., and vehicle fault information, for example, heating is not requested via the control signals (arrow **161**) if the inlet transducer **60** (see FIG. **2**) is broken.

Referring to FIG. **2**, the controller **30** ultimately executes suitable control actions in response to a diagnosis of the heater **28** and pump **50**. As part of such control actions, the controller **30** may output diagnostic codes (arrows **55** and **57**) for the heater **28** and pump **50**, respectively, with each diagnostic code having a corresponding pass or fail status. Other control actions may include illuminating a warning lamp, transmitting a code to a remote location or portable device, repair or replacement of the heater **28** or pump **50**, etc.

The thermal system **20** shown in FIG. **2** includes fluid conduit **25**, **125**, e.g., lengths of pipe, tubing, and/or hydraulic/pneumatic hose and any required fittings. Underhood components of the thermal system **20** are included on a first side (arrow **54**) of an imaginary dividing line **52**. The other side of the line **52** is indicated by arrow **56**, and represents the battery coolant elements of the thermal system **20** evaluated via the present approach.

On the battery coolant side (arrow **56**), the battery pack **18** receives the fluid conduit **25** and routes the fluid conduit **25** internally in proximity to heat-generating elements such as conductive battery cells (not shown). Fluid (arrow **22**) is moved into the battery pack **18** by suction generated by the pump **50**. The speed of the pump **50** is ultimately controlled using speed signals (arrow **72**) transmitted to the pump **50** by the controller **30**, or by another suitable control device.

The heater **28** of FIG. **2** is positioned just upstream of the battery pack **18**. A temperature sensor **60** such as a thermocouple is positioned downstream of the heater **28** at or near a fluid inlet to the battery pack **18**. A similar sensor **62** may be positioned at the outlet of the battery pack **18**, and used, for instance, to evaluate the actual cooling occurring across the battery pack **18**. Temperature signals (arrows **160**, **162**) from the respective temperature sensors **60**, **62**, are fed to the controller **30** over the communications bus **15** of FIG. **1** or wirelessly during the course of execution of the present method **100**, an example of which is shown in FIG. **3** and described below.

Still referring to FIG. **2**, the underhood side, i.e., the side indicated by arrow **54**, may include a radiator **40** and condenser **42** of the type known in the art. Fluid flow (arrows **43**) within the fluid conduit **25** ultimately passes to a node **81**, where the various fluid flows (arrows **43**) coalesce into a single stream to define the flow of fluid (arrow **22**) that is ultimately drawn into the pump **50**. A four-way coolant mode valve **82** may be used to divert some of the fluid (arrow **22**) used in the thermal system **20** to a chiller **46** as shown. For instance, the valve **82** may divide the flow of fluid (arrow **22**) such that a flow (arrow **47**) enters the chiller **46**, a flow (arrow **43**) enters the radiator **40**, and a flow (arrow **45**) reaches node **81**. The chiller **46** may be part of an air conditioning system having an air conditioning compressor **48**, the function of which is controlled via an air conditioning control module **49**, or optionally via signals (arrow **70**) when the controller **30** includes such functionality.

The air conditioning compressor **48** shown in FIG. **2** delivers refrigerant flow (arrows **41**) to the condenser **42**, and ultimately to the chiller **46** via a thermal expansion valve **80**. A similar thermal expansion valve **180** may be used in conjunction with an evaporator **44**. All components of the thermal system **20** of FIG. **2** are shown schematically in FIG. **2**. As will be appreciated by those having ordinary skill in the art, the thermal system **20** may include additional fluid control components and sensors to fully embody an air conditioning system having the desired functionality. However, in order to properly function in accordance with the method **100** described below, all embodiments of the thermal system **20** must include at least the pump **50** and the heater **28**, i.e., a flow device for circulating fluid (arrow **22**) to the battery pack **18** and a heating device configured to raise the temperature of the fluid (arrow **22**) as needed.

Referring to FIG. **3**, an example method **100** is shown for diagnosing the performance of the pump **50** even when operation of the heater **28** is not required, unlike conventional approaches requiring concurrent operation of the heater **28** for evaluation of the pump **50**. The controller **30**, in executing the method **100**, takes advantage of opportune conditions to save energy and decrease unnecessary cycling of the heater **28**.

Beginning with step **102**, the controller **30** of FIGS. **1** and **2** first detects an enabling signal, such as a key-on event in which the vehicle **10** is running, and then proceeds to step **104**. Step **102** is therefore a precondition to execution of the remainder of method **100**.

At step **104**, once execution of the method **100** has been enabled at step **102**, the controller **30** turns on the pump **50** shown in FIG. **2**. The pump **50** begins to circulate fluid (arrow **22**) through the battery pack **18**. The method **100** proceeds to step **106** while the fluid (arrow **22**) continues to flow.

At step **106**, the controller **30** next receives the temperature signals (arrow **160**) from the temperature sensor **60**, or alternately from any other temperature sensor positioned in the flow of fluid (arrow **22**), and then calculates the absolute value of the temperature gradient of the fluid (arrow **22**). The calculated absolute value of the temperature gradient is compared to a calibrated rate. If the absolute value of the temperature gradient exceeds the calibrated rate, i.e., the temperature of the fluid **22** is rising or falling faster than could naturally occur absent flow of the fluid (arrow **22**), the method **100** proceeds to step **108**. Otherwise, the method **100** proceeds to step **110**.

At step **108**, the controller **30** records a diagnostic code for the pump **50** (arrow **57** of FIG. **2**) with a status indicating that the pump **50** is functioning properly. The method **100** then proceeds to step **112**.

At step **110**, the controller **30** next runs a heater diagnostic. For instance, the controller **30** may turn off the pump **50** and turn on the heater **28**. The heater **28** remains on for a calibrated duration, after which the controller **30** turns the heater **28** back off again. A slug of heated fluid (arrow **22**) is generated by this step. The method **100** then proceeds to step **114**.

At step **112**, the controller **30** determines whether battery heating has been requested via the control signals (arrow **161**) shown in FIG. **1**. The control signals (arrow **161**) used in step **112** could be automatically generated, for instance, when outside temperature or an internal temperature of the battery pack **18** drops below a calibrated minimum threshold. If heating has not been requested, the method **100** proceeds to step **122**. Otherwise, the method **100** proceeds to step **110**.

At step **114**, as a result of step **112** the controller **30** shown in FIGS. **2** and **3** should see a rise in the inlet temperature to the battery pack **18**, as measured by the temperature sensor **60**. Acting on this assumption, the controller **30** compares the inlet temperature (arrow **160**) to an expected temperature rise, and proceeds to step **116** if the expected temperature rise is detected. Otherwise, the method **100** proceeds to step **118**.

At step **116**, the controller **30**, having detected the expected rise in temperature at step **114**, runs a subsequent diagnostic of the pump **50**. Step **116** may entail turning the pump **50** back on, a control action which should result in a drop in temperature of the fluid (arrow **22**) entering the battery pack **18** of FIGS. **1** and **2** as measured by the temperature sensor **60**. The method **100** proceeds to step **120**. The execution of step **116** may provide a second diagnosis of the pump **50** if the criteria in step **106** were not met. Thus, the pump **50** is always evaluated, but unlike conventional methods, the heater **28** is only evaluated in response to a negative result at step **106** or a request for heating at step **112**.

At step **118**, the controller **30** records a failing diagnostic code for the heater **28** in memory device **36**. Subsequent control actions may be taken as a result of step **118**, including repair or replacement of the heater **28** and/or illumination of an indicator lamp.

At step **120**, the controller **30** next records a passing or failing diagnostic code for the pump **50** depending on the result of step **116**. That is, if the expected temperature drop as measured by the temperature sensor **60** occurs, the controller **30** records the diagnostic code in the memory device **36** with a corresponding passing status. If the expected temperature drop does not materialize within a calibrated window, however, this indicates either an unexpectedly slow performance or a failure of the pump **50**. In this instance, the controller **30** records the diagnostic code with a corresponding failing status. As with step **118**, any appropriate control actions may be taken as a result of a failing pump diagnostic code, including repair or replacement of the pump **50**, illumination of a warning lamp, etc.

At step **122**, the controller **30** completes method **100** by recording a diagnostic code indicating an incomplete evaluation of the heater **28**. That is, step **112** is arrived at after successful evaluation of the pump **50** at step **108**. Because heating is not requested at step **112**, the heater diagnostic of step **110** is not executed in the present diagnostic cycle.

Execution of the method **100** described above thus results in four possible diagnostic results: a failing heater **28**, regardless of the performance of the pump **50**; a passing pump **50** with a passing heater **28**; a passing pump **50** without diagnosing the heater **28**; and a failing pump **50** with a passing heater. The present approach satisfies on-board diagnostic (OBD) requirements in a relatively energy efficient manner by minimizing the unnecessary use of electrical energy and excessive cycling of high-voltage components.

While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims.

The invention claimed is:

1. A system comprising:

a battery pack;

a supply of heat transfer fluid;

a heater;

a pump that circulates the fluid to the battery pack through the heater;

a temperature sensor configured to measure a temperature of the fluid; and

a controller in communication with the temperature sensor, the pump, the battery pack, and the heater, wherein the controller includes a processor and tangible, non-transitory memory on which is recorded instructions for diagnosing the performance of the heater and the pump;

wherein the controller, via the processor, receives and processes temperature signals from the temperature sensor, and is configured to:

turn on the pump in response to a received enabling signal;

calculate a temperature gradient of the coolant entering the battery pack using the temperature signals while the pump remains on;

record a passing pump diagnostic code if the absolute value of the calculated temperature gradient exceeds a calibrated rate in the form of a calibrated temperature gradient value; and

execute a heater diagnostic, after calculating the temperature gradient, only when heating is requested or the absolute value of the calculated temperature gradient does not exceed the calibrated temperature gradient value, including turning off the pump, cycling the heater on and off, and monitoring the temperature signals for a calibrated temperature rise.

2. The system of claim **1**, further comprising an electric traction motor that is electrically connected to the battery pack.

3. The system of claim **2**, further comprising a transmission having an output member connected to a set of drive wheels, wherein the electric traction motor delivers torque to the transmission using electrical energy drawn from the battery pack.

4. The system of claim **3**, wherein the controller detects a key-on state of a vehicle as the enabling signal.

5. The system of claim **1**, wherein the controller is configured to record a failing heater diagnostic code when the calibrated temperature rise does not occur.

6. The system of claim **1**, wherein the controller is further configured to run a pump diagnostic when the calibrated temperature rise occurs, and to record a passing or failing pump diagnostic code corresponding to the result of the pump diagnostic.

7. The system of claim **6**, wherein the pump diagnostic includes turning on the pump after cycling the heater, detecting the presence or absence of a calibrated drop in temperature of the fluid using the temperature signals, and recording a passing or failing pump diagnostic code when the calibrated drop in temperature is present or absent, respectively.

8. The system of claim **1**, further comprising an air conditioning compressor and a chiller, wherein the fluid is passed from the chiller to the pump.

9. A method for diagnosing a system having a battery pack, heat transfer fluid, a heater, and a pump that circulates the fluid to the battery pack through the heater, the method comprising:

measuring a temperature of the fluid;

receiving an enabling signal via a controller;

turning on the pump, via a controller, in response to the received enabling signal;

calculating, via the controller, an absolute value of a temperature gradient of the fluid using the temperature signals while the pump remains on;

recording a passing pump diagnostic code if the absolute value of the temperature gradient exceeds a calibrated rate in the form of a calibrated temperature gradient value; and

executing a heater diagnostic, after calculating the absolute value of the temperature gradient, only when battery heating is requested or the absolute value of the temperature gradient does not exceed the calibrated temperature gradient value, including turning off the pump, cycling the heater on and off, and monitoring the temperature signals for a calibrated temperature rise.

10. The method of claim **9**, further comprising: detecting a key-on state of a vehicle as the enabling signal.

11. The method of claim **9**, further comprising: recording a failing heater diagnostic code when the calibrated temperature rise does not occur.

12. The method of claim **9**, further comprising: executing a pump diagnostic using the controller when the calibrated temperature rise occurs, and recording a passing or failing pump diagnostic code corresponding to the result of the pump diagnostic.

13. The method of claim **12**, wherein executing the pump diagnostic includes:

turning on the pump after cycling the heater;

detecting the presence or absence of a calibrated drop in temperature of the fluid using the temperature signals; and

recording a passing or failing pump diagnostic code when the calibrated drop in temperature is present or absent, respectively.

14. A method for diagnosing a thermal system in a vehicle, wherein the thermal system includes a battery pack, heat transfer fluid, a heater, and a pump that circulates the fluid to the battery pack through the heater, the method comprising:

measuring a temperature of the fluid at a point in which the fluid enters the battery pack;

detecting a key-on state of the vehicle as an enabling signal;

receiving the enabling signal via a controller;

turning on the pump, using the controller, in response to receipt of the enabling signal;

calculating, via the controller, an absolute value of a temperature gradient of the fluid the battery pack using the temperature signals while the pump remains on;

recording a passing pump diagnostic code if the calculated absolute value of the temperature gradient exceeds a calibrated rate in the form of a calibrated temperature gradient value;

executing a heater diagnostic, after calculating the absolute value of the temperature gradient, only when battery heating is requested or the calculated absolute value of the temperature gradient does not exceed the calibrated rate, including turning off the pump, cycling the heater on and off, and monitoring the temperature signals for a calibrated temperature rise;

recording a failing heater diagnostic code in memory of the controller when the calibrated temperature rise does not occur; and

executing a pump diagnostic using the controller when the calibrated temperature rise occurs, including turning on the pump after cycling the heater, detecting the presence or absence of a calibrated drop in temperature of the fluid using the temperature signals, and recording a passing or failing pump diagnostic code when the calibrated drop in temperature is present or absent, respectively.

* * * * *